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The opportunity of power electronics on improving the quality of voltage and power flow in the west Algeria network

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Abstract

The Flexible Alternate Current Transmission Systems (FACTS) controllers improve quality of the supply power, enhance power system performance and also provide an optimal utilization of the existing resources. Especially the Thyristor Controlled Series Compensator (TCSC) and the Static Var Compensator (SVC) has been proposed to enhance the power transfer capability and improve the quality of the voltage by adjusting the line reactance. This paper, present a study of the west Algerian 2012 network. Furthermore, we will try to ask some problems encountered in practice, to find solutions and moving towards the FACTS devices in particular the TCSC and SVC controller, its application and technical advantage. The software NEPLAN is used to analyse the behaviour of the West Algerian electrical network without and with FACTS devices.

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Keywords: Power flow- Newton Raphson method- Flexible Alternate Current Transmission Systems (FACTS)-Thyristor Controlled Series Compensator (TCSC) - Static Var Compensator (SVC).

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1. Introduction

In recent years, production, transport and consumption of electrical energy have been increasing due to industrialization, population growth and urbanization [1].

To face these problems and considering the ecological and economic difficulty of the construction of new lines, a solution was adopted as from 1988 by American company EPRI (Electric Power Research Institute). This solution is based on the launch of a project to study a new generation of devices classified under the label controller FACTS (Flexible Alternate Current Transmission Systems). FACTS use the opportunities of power electronics in the control, control of power transmission AC and with an only purpose of controlling the transit of power in transmission lines and improve the quality of the voltage at bus [2].

The concept of FACTS was born to answer the various increasing difficulties of power transmission in the electrical network especially to control the power flow, the bus voltage and to enhance the stability of the system [3].

The static compensators are complex systems using electronic switches, circuit breakers, capacitors and automatisms based on microprocessors. They are able to regulate the electric parameters of the network (voltage, impedance, phase…) in a wide range, for powers, and constraints of environment increasingly more important [4].

Nomenclature

FACTS	Flexible Alternate Current Transmission Systems
TCSC	Thyristor Controlled Series Compensator
SVC	Static Var Compensator
TCR	Thyristor controlled reactor
TSC	Thyristor switched capacitor
STATCOM	Statatic synchronous condenser
UPFC	Unified Power Flow Controller

2. Typical applications of FACTS in electric power systems:

The application of FACTS controllers in the power system can obtain, one or more of the following benefits [4,5] :

- Control of power flow in the electric network ;
- To increase the possibilities of loading of the lines close with their thermal limits;
- Improve transient stability ;
- To compensate the reactive power;
- To improve the dynamic stability of voltage;
- Damping of the oscillations of the power;
- To attenuate the imbalance of voltage due to the single-phase loads.

Systems FACTS are usually known like new technology, but a hundreds of installations are in the world, more particularly the SVC since 1970 with a total power installed of 90000 MVAR; prove the acceptance of this kind of technology. The table.1 shows estimative numbers of devices FACTS installed in the world with the total powers installed [6] .

Table 1. Devices FACTS installed in the world and their total powers

Type of FACTS	Number	Installed power [MVA]
SVC	600	90000
STATCOM	15	1200
TCSC	10	2000
HVDC.B2B	41	14000
UPFC	23	250

Several work showed the effectiveness of the use of the FACTS. Although there exist many successful examples of installation [7].

2.1. SVC device

The static compensators are used in the networks in the form of elements shunts of reactive power (inductances, condensators) commanded by thyristors assembled in head-digs on each phase, each one of them being conducting during a half-period. The figure below gives a diagrammatic representation of a static compensator single-phase.

It is composed of a reactance X_C whose provided reactive power which can be completely commanded or completely started and of an induction coil with inductive reactance X_L whose absorptive reactive power between zero and its maximum value by thyristors assembled as quoted previously head-digs to ensure of the very fast inversions of the current [7,8].

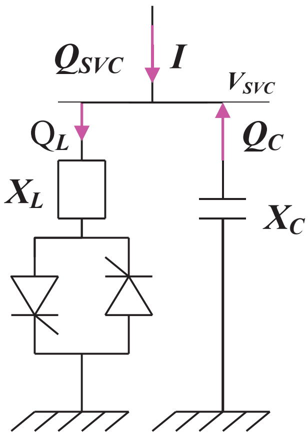

Fig. 1. Single-phase diagrammatic representation of a compensator

The reactive power Q_{SVC} varies between an inductive value Q_{ind} and capacitive value Q_{cap}.
With:

$$Q_{cap} = \frac{V_{SVC}^2}{X_C} \tag{1}$$

We obtain the capacitive reactance X_C necessary for the capacitor by using the relation:

$$Q_{ind} = \frac{V_{SVC}^2}{X_L} - \frac{V_{SVC}^2}{X_C} \tag{2}$$

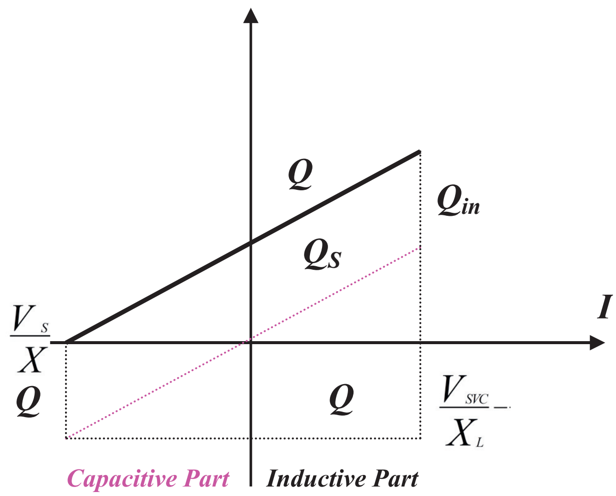

Fig. 2. Requirements for power

A SVC device is generally composed of TCR: It is a reactance in series with a gradator and its value is continuously variable according to the angle of starting of the thyristors.

TSC: capacities controlled by thyristors functioning in full wave.

2.2. TCSC device

TCSC it's a device of series compensation, it uses the power electronic as basic element. It is connected in series with the network for control transit of power, the damping of resonance subsynchrone and the oscillations of power. This type of compensator appeared in the middle of the Eighties [8].

The TCSC is composed of an inductance in series with a gradator of thyristors; all in parallel with a capacitor as shown on the figure.3.

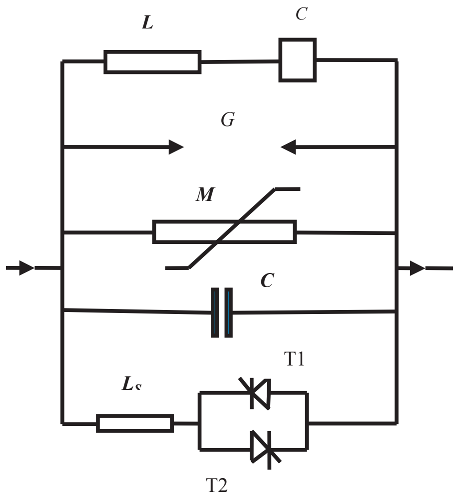

Fig. 3. The structure of the TCSC

As the basic components of the voltage and the current are controlled, the TCSC becomes similar to controllable impedance, which is the result of the parallelization of the equivalent reactance of a component TCR and a capacity.
Let us note by: [8]

$$Z_{TCSC} = jX_{TCSC} \tag{3}$$

Equivalent impedance of the TCSC.

$$Z_{TCR} = jX_{TCR} = j\frac{X_L \pi}{2(\pi - \alpha) + \sin 2\alpha} \tag{4}$$

Equivalent impedance of the TCR.

$$Z_C = -jX_C \tag{5}$$

Impedance of the capacity

Since:

$$Z_{TCSC} = Z_C \,//\, Z_{TCR} = \frac{-jX_C . jX_{TCR}}{-jX_C + jX_{TCR}} \tag{6}$$

$$= j.\frac{X_C . X_L}{\frac{X_C}{\pi}(2(\pi - \alpha) + \sin 2\alpha) - X_L} \tag{7}$$

Where

$$X_{TCSC}(\alpha) = \frac{X_C X_L}{\frac{X_C}{\pi}(2(\pi - \alpha) + \sin 2\alpha) - X_L} \tag{8}$$

The TCSC placed in series in transmission line makes it possible to control the flow of power and to raise the capacity of transfer of the lines while acting on the reactance X_{TCSC} which varies according to the angle of firing delay thyristor α given by equation (4).

3. Application

The objective of this paper, is to apply the calculation of power flow by the Newton-Raphson method's to the West Algeria 400 /220KV and 60KV network, while inserting to him controllers FACTS (TCSC and SVC) by using a tool for simulation of topicality (software NEPLAN).
NEPLAN is a very convivial tool for the users of information and planning system for the electrical networks.

The network represented by the fig. (4) includes:

- 102 bus;
- 07 bus generation;
- 03 compensation bus ;
- 92 load bus ;
- 138 lines

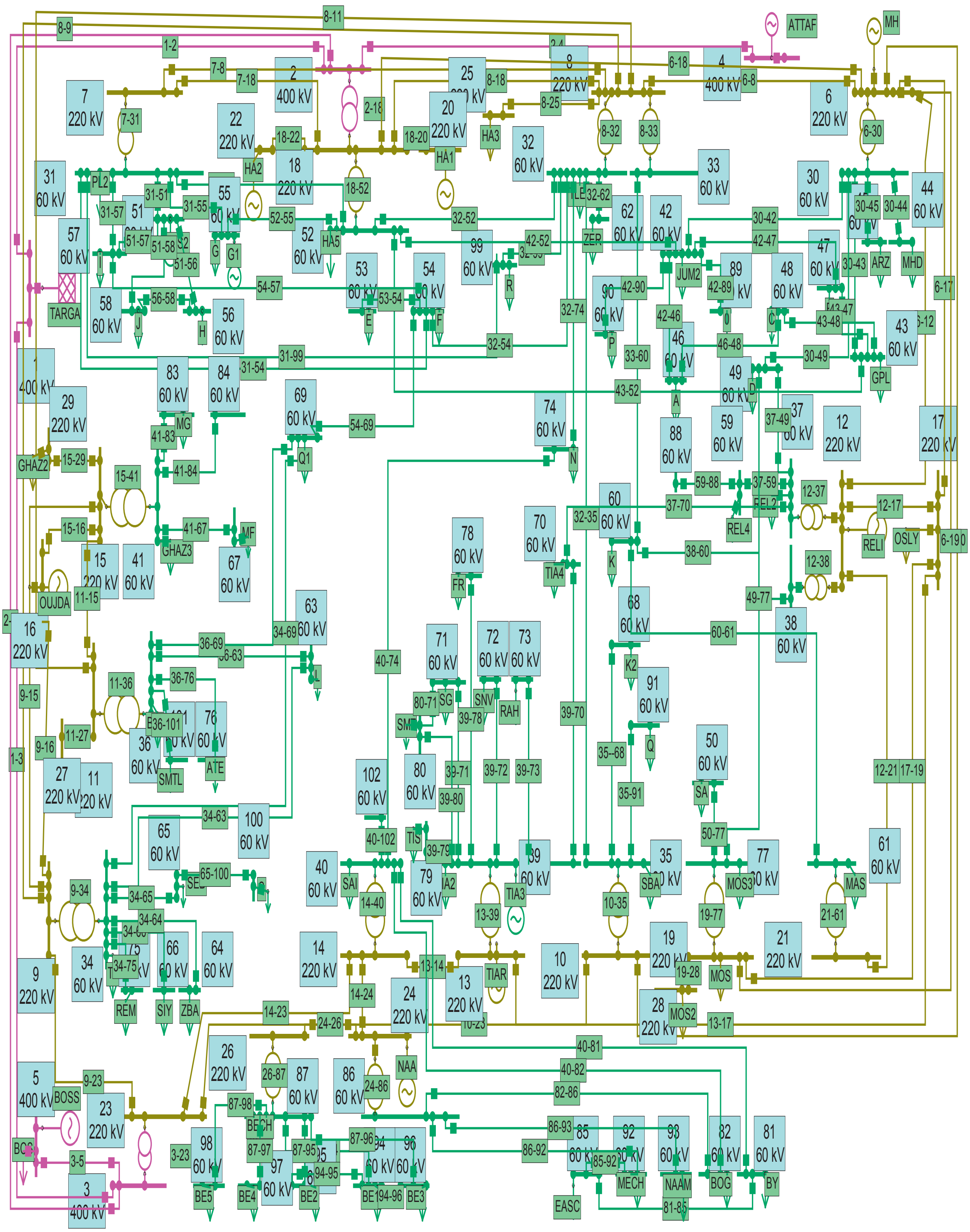

Fig. 4. Diagram of the West-Algeria (2012) network, inserted in NEPLAN

3.1. Network without device FACTS analyzes

The analysis of our network is achieving using software. This last, we allow the calculation of the power flow. It includes also the operation and the order of devices TCSC and SVC.

The calculation of the power flow is a stage necessary to be able to compare our results. It is made initially for the determination of the initial conditions of the system before the compensation. Indeed, it makes it possible to find the voltages of the various nodes and thereafter the powers transmitted, injected and losses Fig. (5) et Fig. (6).

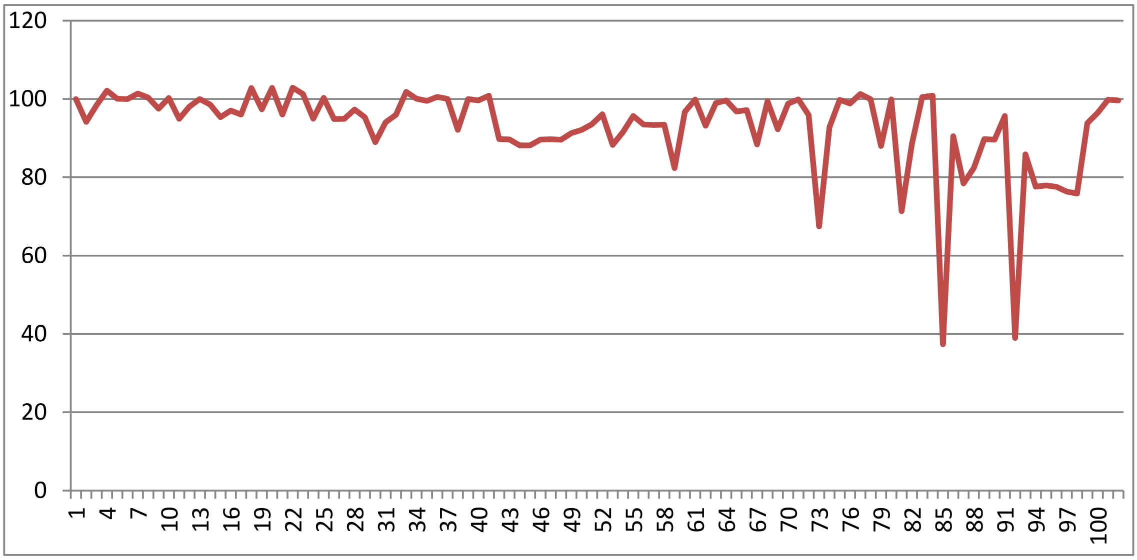

Fig. 5. Bus Voltages of the network in West-Algeria (2012) without FACTS

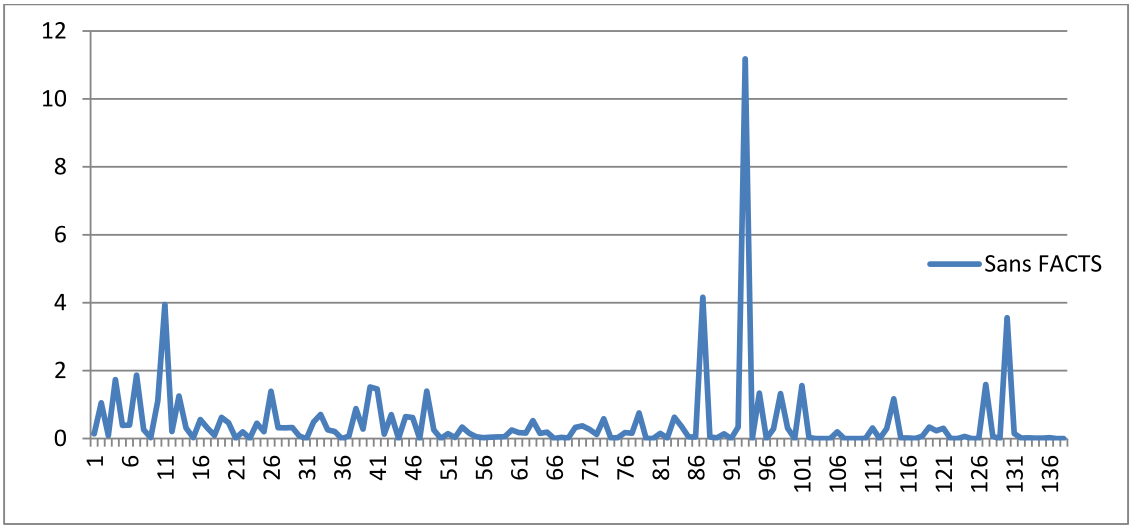

Fig. 6. Active losses of the West-Algeria (2012) network without FACTS

3.2. Problems of the West- Algeria network

According to the results of the power flow preceding as indicated in figures 5 and 6, we can conclude that this network suffers from two problems, the first it is the transit of power especially in the longest lines such as Bechar-Naama and Naama- Saida, the second problem it is the fall and overvoltage especially on the level of bus 4, 73,85 and 88.

It is necessary to solve these problems using the controllers FACTS containing the power electronic, we must use the series compensation and the parallel compensation.

We must insert a TCSC and a SVC in the network West-Algeria to solve these problems, but when we will install these devices? Which are the parameters of adjustment of these devices?

3.3. Parameters with TCSC device

To find the optimal site of this device, we must observe the following theoretical conditions:

- This device must be placed in the longest lines.
- This device must be placed in the lines which are far from the production.
- That the site is profitable of point of considering cost.

After a long research task of the optimal site of the TCSC, we found that the line (24-26) satisfied these conditions seeing figure 7. There exist several strategies of operation or control. In our case, we chose the strategy of control by the angle of transmission of modulation because it is to regard as better strategy of adjustment.

The parameters chosen are as follows:

The basic value is: Sb =100 MVA

The parameters controller of the TCSC are :

- The frequency f= 50 Hz
- The inductive reactance X_L = 0,391 Ohm
- The capacitive reactance X_C = 1,414 Ohm

After we found the optimal site, it is necessary to also find the angle of optimal adjustment which records the least quantity of losses in the network.

After a long research task of this angle, we found the angle of adjustment as follows :

The angle of adjustment α=138, 63°
The angle minimal α_{min}=135, 25°
The angle maximum α_{max}=180°

3.4. Parameters with SVC device

We have choose to improve quality of the tension for two nodes most unfavorable overvoltage on the level of node 4 and the voltage drop at the level them bus 85 , see figure 7.

For the N°04 bus we have an overvoltage, the SVC will absorb power reactivates it is the inductive effect of the SVC.

After a long research task we found: Qc=120 Mvar.

For the N°85 bus we have a voltage drop, the SVC will inject power reactivates it is the capacitive effect of the SVC.

The same thing is made that the preceding one we found: Qc= - 18 Mvar.

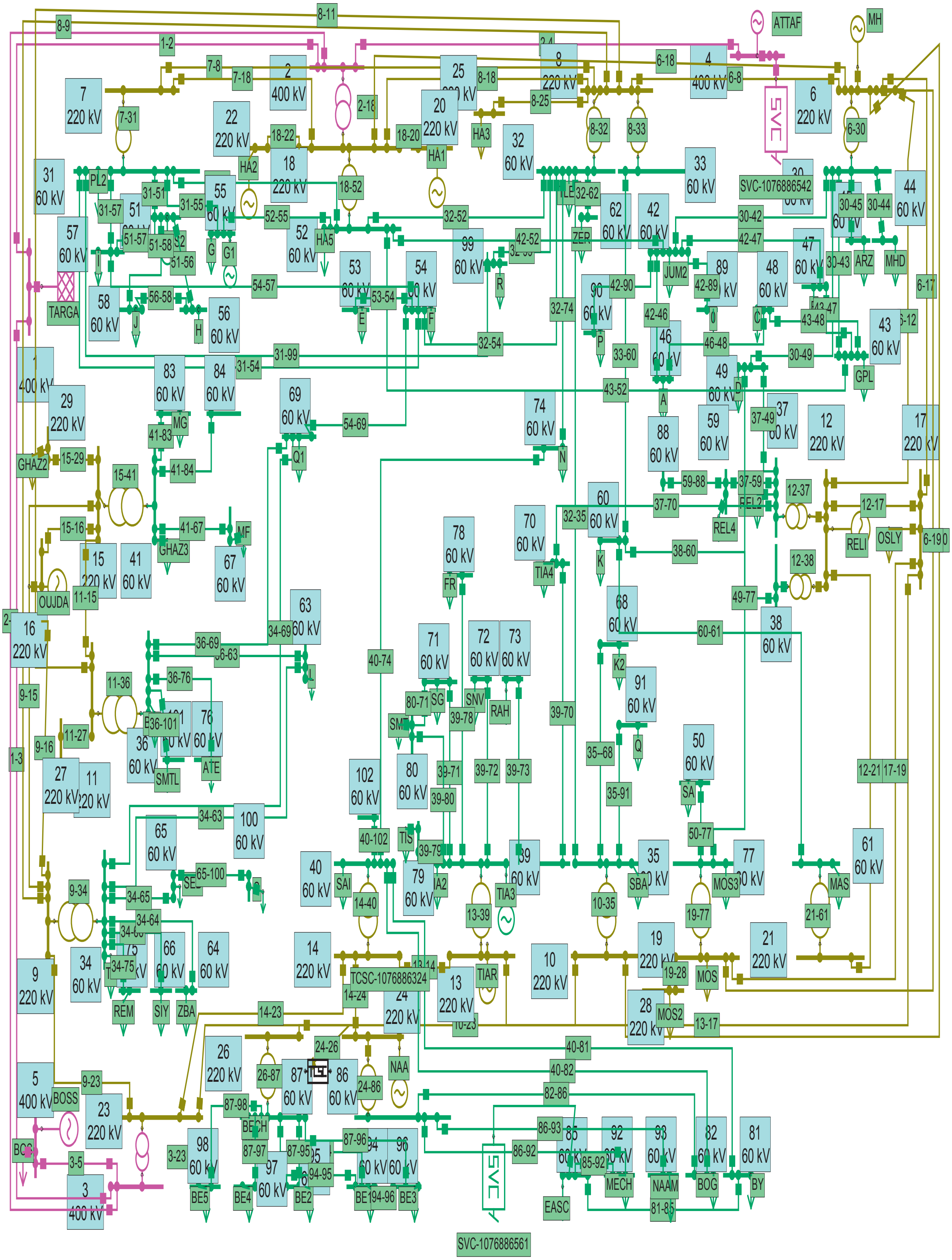

Fig. 7. West-Algeria (2012) network with FACTS

The power flow calculation of the system with insertion of device TCSC in the line chosen according to the criteria of the line (24-26), and both SVCs in bus 4 and 85, the results obtained are in figures 8 and 9.

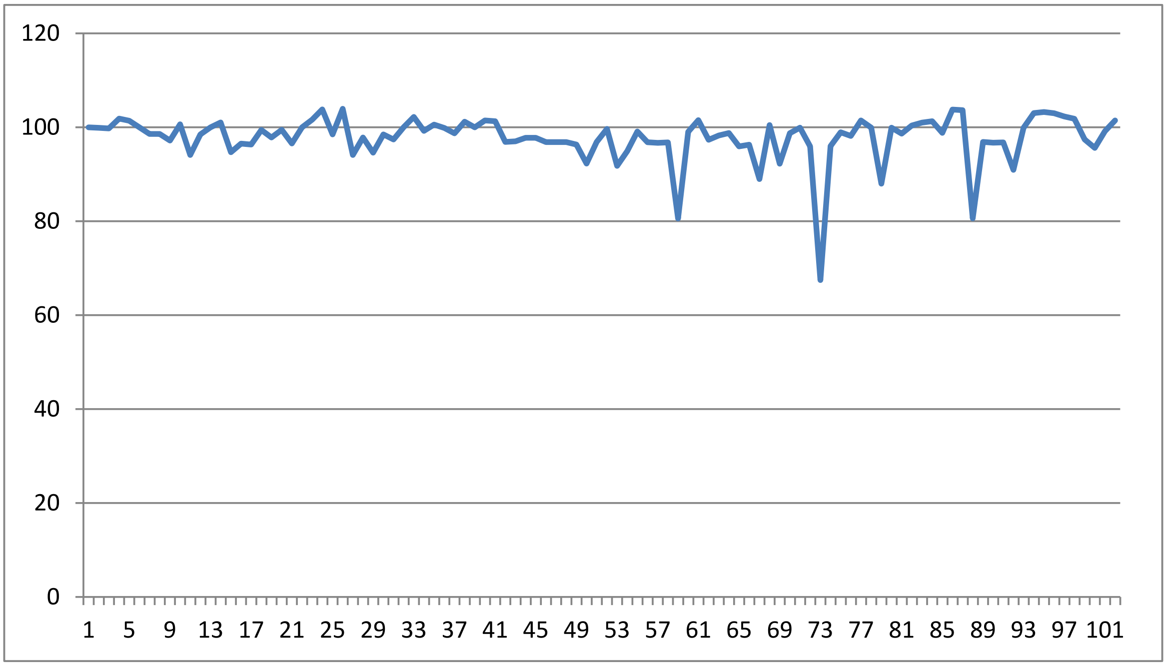

Fig. 8. Bus voltage of the West-Algeria (2012) network, with FACTS

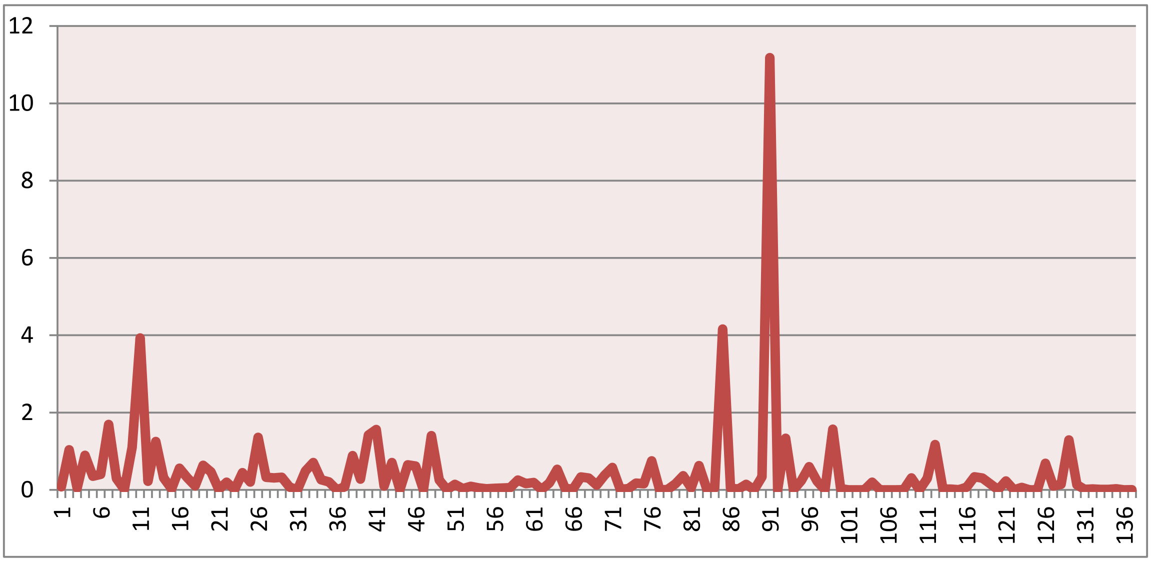

Fig. 9. Active losses in the West-Algeria (2012) network, with FACTS

4. Interpretation

Table 2. Results Comparison of series compensation

Results	Without TCSC	With TCSC	Better Branch emplacement
Active losses [MW]	63,5531	58,1179	(24-26)

Table 3. Results Comparison of parallel compensation

Bus number	Voltage Without SVC [pu]	Voltage With SVC [pu]
04	1,09	1.00
85	0,63	0,99

According to the results obtained table.2 we notices that the total system losses decreased by 63, 5531 MW to 58, 1179 MW, That is to say a profit of 5, 4352 MW. This reduction is obtained with device TCSC between the lines (24-26) which corresponds to the optimal location. This last is not arbitrary because, we chose it among other sites by respecting the criteria of insertion of the controller.

We justified the criteria of the site choice of this device, because it is about a strategic line 220 kV in the West-Algeria network, which feeds the south-west area. Then we will solve the problem of power flow for a whole area not only one point it is for that our choice is profitable.

With the parallel compensation, the results obtained in Table.3 show clearly that the voltages are improved, the overvoltage of bus 04 decreases by 1,09 to 1,00 and voltage drop of node 85 increased by 0,63 pu to 0,99 and this has been achieved by the presence of the two SVC at these two bus.

5. Conclusion

This study presents and explains the control of the active power and the improvement of the quality of the voltage in a system of energy by controllers FACTS containing the power electronics. The FACTS chosen for this control are the TCSC and SVC devices. The TCSC is a powerful and flexible system that provides benefits especially for long distance power transmission systems and the SVC device permet to minimize the losses in the transmission system. The simulation carried out on west Algeria system validates the effectiveness of this FACTS. The simulation results show that by installing TCSC and SVC controllers at suitable locations, the system can be operated with voltage security even under severe line outages.

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